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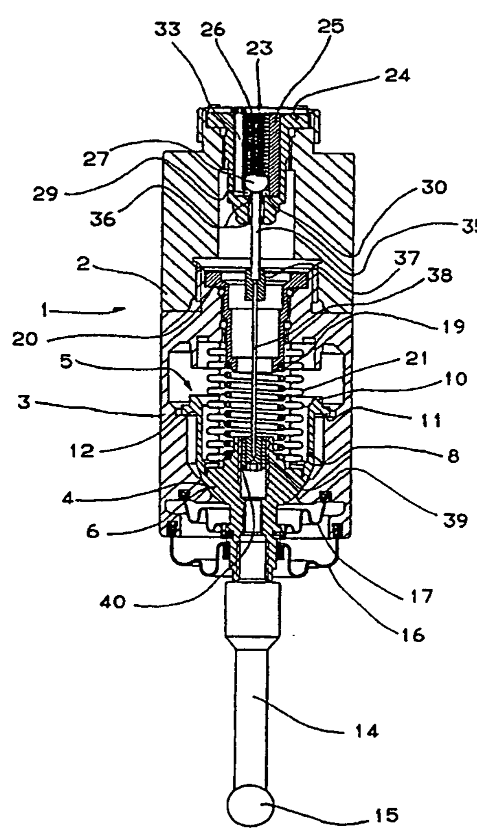
(54) Title: HEAD FOR THE LINEAR DIMENSION CHECKING OF MECHANICAL PIECES

(57) Abstract

A head for the linear dimension checking of mechanical pieces, including a casing (1), that defines a longitudinal geometric axis, an arm–set (5), movable with respect to the casing, a feeler (15), coupled to the movable arm–set, for touching the piece to be checked, a bias device (19), arranged between the casing and the movable arm–set for urging the movable arm–set into contact with the casing, a detecting device (23), coupled to the casing, including a movable element (27), and a transmission device (35,38) between the movable arm–set and the movable element of the detecting device. In order to reduce the frictions and improve the repeatability of the head, the transmission device includes a wire (38), substantially rigid in a longitudinal direction but flexible in the directions perpendicular to the longitudinal direction. The wire has a first end coupled to the movable arm–set and a second end for cooperating with the movable element of the detecting device.



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DESCRIPTION

«HEAD FOR THE LINEAR DIMENSION CHECKING OF MECHANICAL PIECES»

Technical Field

The present invention relates to a head for the linear dimension checking of mechanical pieces, including a casing, that defines a longitudinal geometric axis, an arm-set, movable with respect to the casing, a feeler, coupled to the movable arm-set, for touching the piece to be checked, a bias device, arranged between the casing and the movable arm-set for urging the movable arm-set into contact with the casing, a detecting device, coupled to the casing, including a movable element, and a transmission device between the movable arm-set and the movable element of the detecting device.

Background Art

Contact detecting and measuring heads of the type described are known from US-A-5299360.

The mechanic structure of these heads, based on a coupling between the movable arm-set and the casing, achieved by means of a first constraining system substantially of the cone-ball type and a second constraining system for preventing rotations of the movable arm-set about the longitudinal geometric axis, and on the presence of two annular facing surfaces adapted to enter into a substantially point-to-point contact, guarantees good repeatability.

However, in some applications, it is required that the repeatability errors be as small as possible, considerably smaller than 1 μm.

The repeatability errors are mainly due to the effects of frictions among reciprocally moving parts, to shape errors

of elements of the head, and to vibrations due to shock waves or other dynamic phenomena.

This is particularly true with regard to the detecting device and its arrangement in the head. More specifically, a detecting device disclosed in US-A-5299360 includes a microswitch with a stem having an end adapted for contacting the movable arm-set. This contact may involve slidings and thus repeatability errors. Moreover, as the stem of the microswitch is not constrained with respect to rotations about its axis, and it is possible that there may be errors in the shape of the stem, other repeatability errors may consequently possibly arise.

From the article "Multi-directional probe" published on pages 7 and 8 of the publication "Technical Digest No. 6, April 1967" of the American company Western Electric, there is known a measuring probe with a housing, that defines a frusto-conical cavity, a position transducer measuring device fixed at the interior of the housing, and a movable arm-set with shaped portions for providing contact and a frusto-conical portion for cooperating with the frusto-conical cavity of the housing. The measuring device includes a movable element coupled to an end of a wire, axially rigid but flexible in transversal directions. The other end of the wire is connected to the movable arm-set. Moreover, the measuring device includes means, not shown, that presumably consist of an internal spring, that, by means of the movable element and the wire, urge the frusto-conical portion of the movable arm-set towards the frusto-conical cavity of the housing.

Therefore, the wire is subject to a compressive stress of a considerable entity, owing to the fact that it has to apply force for causing contact between the movable portion of the arm-set and the cavity of the housing. Consequently, problems arise insofar as the dimensions of the section of the wire are concerned, because of the contrasting requirements of providing resistance to a considerable compressive stress on the one hand and achieving good

lateral flexibility on the other. Moreover, even the frictional forces acting on the wire necessarily have relatively high values.

Disclosure of Invention

Object of the present invention is to provide a checking head in which the component of the repeatability error due to the detecting device is particularly small.
This and other objects are achieved by a checking head of the herein described type in which the transmission device includes a wire, substantially rigid in said longitudinal direction but flexible in the directions perpendicular to the longitudinal direction, the wire having a first end coupled to the movable arm-set and a second end for cooperating with the movable element of the detecting device.
The invention enables to achieve negligible frictional forces in the transmission device and in the detecting device, avoid problems insofar as the design sizes of the transmission device are concerned and, in conclusion, considerably improve the head repeatability.

Brief Description of the Drawings

Other objects and advantages of the invention or of specific embodiments of the invention will appear from the following detailed description that refers to preferred embodiments illustrated in the enclosed sheets of drawings, given by way of non limiting example, wherein:

figure 1 is a longitudinal cross-sectional view of a contact detecting head according to a first embodiment of the invention;

figures 2a, 2b and 2c are enlarged scale, longitudinal cross-sectional views of a detail of the head of figure 1 according to three possible variants;

figure 3 schematically shows, in an enlarged scale

with respect to that of figure 1, a longitudinal cross-sectional view of some components of the head of figure 1, according to a different embodiment of the invention;

figure 4 is a cross-sectional view taken along the line IV-IV of figure 3;

figure 5 shows a detail of the head of figure 3;

figure 6 is a variant of the components of the head shown in figure 3;

figure 7 is cross-sectional view taken along the line VII-VII of figure 6;

figure 8 shows a further variant of the components of the head shown in figures 3 and 6; and

figure 9 is a longitudinal cross-sectional view of a measuring head according to a third embodiment of the invention.

Best Mode for Carrying Out the Invention

The contact detecting head shown in figure 1 includes a casing **1**, with a substantially cylindrical shape, consisting of two superimposed portions **2** and **3**, coupled by means of a threaded coupling, that define a longitudinal geometric axis.

In the lower part of portion **3** there is a seat **4** with a substantially frusto-conical surface.

The movable arm-set **5** of the head includes a reference element **6** with a surface having substantially the shape of a spherical zone for engaging with seat **4**, a hollow portion **8**, with a substantially cylindrical shape, integral with the reference element **6**, and an upper flange **10**, integral with the hollow portion **8**, that has an annular portion **11** protruding downwards.

When movable arm-set **5** is in the position shown in figure 1, i.e. symmetric with respect to the longitudinal geometric axis defined by casing **1**, annular portion **11** is at a distance of a few micrometers from a corresponding stationary annular surface **12** formed in a plane recess of

portion **3**.

This clearance, that is not visible in the figure, is fundamental for the repeatability of the head.

Furthermore, movable arm-set **5** includes an arm **14** with a feeler **15**.

Between arm **14** and portion **3** there are two flexible, sealing and protection elements **16** and **17**.

A helical spring **19** has its ends abutting against two plane surfaces formed in reference element **6** and in an abutment element **20** integral with portion **3** of casing **1** and urges the spherical part of reference element **6** towards seat **4**.

As disclosed in patent US-A-5299360, to which reference is made for any further explanation, the herein described coupling between movable arm-set **5** and casing **1** is adapted to eliminate three degrees of freedom of movable arm-set **5**. Another degree of freedom, that relates to rotations of movable arm-set **5** about the longitudinal geometric axis defined by casing **1**, is eliminated by a metal bellows **21**, that houses spring **19** at the interior and has its ends secured to the plane surface of reference element **6** and to another transversal surface of portion **3**.

The contact occurring between feeler **15** and a piece is detected, subsequently to a determinate pre-stroke in a longitudinal direction or, in the case of displacements of feeler **15** in a transversal direction, at a determinate angle between the longitudinal geometric axis of casing **1** and the geometric axis of arm **14**, by means of a detecting device that includes a microswitch **23**.

The microswitch **23** includes a casing **24** with an insulating, cylindrical element **25** that houses a spring **26** for urging a movable element, more specifically a small ball **27**, made of electrically conducting material, into contact with two small bars **29** and **30**, also made of electrically conducting material, secured to insulating element **25** at a lower base of casing **24**.

When small ball **27** contacts bars **29** and **30**, microswitch **23** is closed, whereas when ball **27** disengages from at least

one of bars **29** and **30**, microswitch **23** opens. An external circuit, not shown in the drawings, is connected to bars **29** and **30** by means of conductors, not shown in the drawings, that traverse a longitudinal opening **33**.

Furthermore, microswitch **23** includes a stem **35**, axially guided by means of two sapphire bushings **36** fixed to casing **24** near contact bars **29** and **30**. The lower end of stem **35** is secured at the top of a coupling element **37** that has its lower part secured to the upper end of a flexible wire **38**. The lower end of wire **38** is secured, by means of an insulating bushing **39**, to a coupling and adjustment, threaded dowel **40**, that is centrally coupled, by means of a frictional coupling, to the upper part of reference element **6**.

The wire **38** is made of spring steel and can be, for example, 20 mm long and have a diameter of 0.4-0.5 mm. When feeler **15** is not subject to contact forces with a piece, the upper end of stem **35** is at a short distance from ball **27**. Upon contact with the piece, wire **38** transmits an upward displacement to stem **35**, and the latter contacts - after a determined amount of pre-stroke - small ball **27** and causes it to disengage from bars **29** and **30**, overcoming the force applied by spring **26**, that is relatively small with respect to that applied by spring **19**.

Owing to the amount of the involved forces and the dimensions of wire **38**, the latter is rigid with respect to axial forces, while can deflect in a transversal direction because of the transversal forces that are generated as a consequence of contact occurring between feeler **15** and the piece in a transversal direction.

From the foregoing description, it is obvious that, because the coupling device comprising wire **38** and stem **35** is coupled to movable arm-set **5**, it is also subject to the constraint of bellows **21**.

Furthermore, the frictional forces acting in microswitch **23** and in the coupling device are low in number and value. Hence, the contribution to the repeatability error of the

head provided by microswitch **23** and the coupling device is relatively small (in the range of 0.05-0.1 μm).

Figures 2a, 2b and 2c show how, in order to guide in a more accurate way axial displacements of stem **35** - by limiting the length of its free portion - and to dampen possible vibrations of wire **38**, different (or supplemental) guide devices are provided. In particular, in the embodiment of figure 2a, in addition to one of the two bushings **36** there can be foreseen a guide **42**, made of antifriction material, at the interior of which coupling element **37** slides. Guide **42** is coupled to casing **24**.

Figures 2b shows a different couplig element **37'** including a substantially spherical surface, that slides in a guide **42'** coupled to portion **2** of the casing **1**. Figure 2c shows a substantially cylindrical coupling element **37"** housed in a guide **42"** coupled to portion **2**. A ball bearing **43** is arranged between the coupling element **37"** and the guide **42"**, and no bushings **36** are fixed to the casing **24**.

The guide devices according to figures 2b and 2c guarantee a guiding action involving particularly low friction and stresses.

It is pointed out that, in figures 2b and 2c, portion **2** of the casing **1** and casings **24'** and **24"** are vary schematically shown for the sake of simplicity. In particular, casings **24'** and **24"** are not substantially different with respect to casing **24** of figure 1.

It can be readily understood that the head shown in figure 1 can be modified in such a way as to eliminate stem **35**, so that the upper end of wire **38** is free and can directly act on small ball **27**.

The figures from 3 to 5 show some details of a different microswitch **23'** of a contact detecting head otherwise substantially identical to the one shown in figure 1.

In microswitch **23'** there is not foreseen an axial thrust spring.

Wire **38'** has its upper end directly secured to small ball **27'**.

At the interior of the insulating element **25'**, located in casing **24'** of microswitch **23'**, there are secured two stationary electrodes, or conducting bars, **45** and **46** electrically insulated that, together with small ball **27'** and conductors not shown in the drawings, can close a detecting circuit. The bars **45** and **46** are arranged parallel with respect to the longitudinal geometric axis and side by side in a transversal direction.

A shaped element **49** made from insulating material (for example, ceramic) is also internally secured to insulating element **25'** of microswitch **23'**, substantially at an intermediate position between conducting bars **45** and **46**, and defines an abutment surface.

An elastic thin plate **48** has its upper end clamped to insulating element **25'**, and its free end specifically shaped for urging small ball **27'** towards bars **45** and **46** in such a way as to close microswitch **23'**. In order to facilitate the assembly, thin plate **48** has a window **50** and the end open.

It is obvious that microswitch **23'** is set by operating threaded dowel **40**, as in the embodiment shown in figure 1.

Upon contact occurring between the feeler and the piece, and the subsequent displacing of wire **38'** and thin plate **48**, movable ba**27'** is urged upwards, contacts shaped element **49** and disengages from at least one of stationary bars **45** and **46**, thereby opening microswitch **23'**. Then ball **27'** slides on shaped element **49**, urged towards the latter by thin plate **48**, as shown with dashed lines in figure 3.

Thus, in the head of figure 3, wire **38'** does not undergo any compressive stress and, indeed, can undergo a slight tractive force.

Obviously, as the contact force on the feeler ceases, ball **27'** engages again both bars **45** and **46**.

The absence of elastic compressive stress on wire **38'** is the reason for which the only shock waves being generated as a consequence of feeler **15** contacting the piece are just those due to spring **19** (figure 1), whereas in the probe of

figure 1 even spring **26** of microswitch **23** generates shock waves.

However, these advantages with respect to the head of figure 1 imply a greater structural complexity, hence either of the two solutions can be chosen, depending on the circumstances (application conditions, costs involved, etc.).

Figures 6 and 7 show a microswitch **23''** with some variants with respect to the head of figures 3 to 5. More specifically, conducting bars **45'** and **46'** are arranged in a direction that is inclined with respect to the longitudinal geometric axis. Moreover, a flat element or small plate **44** made of rigid, hard material, like ceramic, is internally fixed to insulating element **25''** of casing **24''** and defines a plane abutment surface arranged in the direction of the longitudinal geometric axis.

The operation of a head including microswitch **23''** is substantially alike that described with reference to figures 3, 4 and 5. More specifically, upon contact occurring between the feeler and the piece, the subsequent displacement of wire **38'** and the thrust of thin plate **48**, movable ball **27'** displaces in the inclined direction defined by stationary bars **45'** and **46'** until it touches the plane surface of plate **44** and disengages from at least one of the formerly mentioned bars **45'** and **46'**, thereby opening microswitch **23''**. Then ball **27'** slides on the plane abutment surface of plate **44**, urged towards it by thin plate **48**, as shown with dashed lines in figure 6.

Figure 8 shows a microswitch **23'''** with further variants with respect to the embodiments illustrated in figures from 3 to 7.

In microswitch **23'''** shown in figure 8, small ball **27'** is made of ferromagnetic material and, instead of being urged by an elastic thin plate towards the stationary contacts, consisting of two small balls (only one, **51**, is shown in the figure), it is attracted towards them and towards the plane abutment surface of an insulating plate **44'** by a

magnetic disk, in particular a permanent magnet **53**, set in plate **44'**.

The structure of the measuring head shown in figure 9 is to a great extent similar to that of the head of figure 1, except for the detecting device that includes a position transducer and the transmission wire that is connected in a different way.

The lower end of wire **38''** is coupled to adjustment dowel **40** as described with reference to wire **38** shown in figure 1. The upper end of wire **38''** is locked in a hole of a substantially cylindrical support **55** that carries in its central part a magnetic core **56**, axially movable within electric windings **57** of an inductive position transducer. The windings **57** are formed in slots of a spool **58** that has an axial hole with a surface that acts as a guide for support **55** and thus for wire **38''**.

So, in the head shown in figure 9, wire **38''** does not undergo significant compressive stresses or tractive forces.

It has been proved that the invention enables to achieve probes suitable for operating in a workshop environment, e.g. for applications in lathes and machining centers, with repeatability errors smaller than 0.2-0.3 μm.

CLAIMS

1. A head for the linear dimension checking of mechanical pieces, including a casing (**1**), that defines a longitudinal geometric axis, an arm-set (**5**), movable with respect to the casing, a feeler (**15**), coupled to the movable arm-set, for touching the piece to be checked, a bias device (**19**), arranged between the casing and the movable arm-set for urging the movable arm-set into contact with the casing, a detecting device (**23;23';23'';23''';56,57**), coupled to the casing, including a movable element (**27;27';56**), and a transmission device (**35,38;38';38''**) between the movable arm-set and the movable element of the detecting device, characterized in that said transmission device includes a wire (**38;38';38''**), substantially rigid in said longitudinal direction but flexible in the directions perpendicular to the longitudinal direction, the wire having a first end coupled to the movable arm-set and a second end for cooperating with the movable element of the detecting device.

2. The head according to claim 1, for detecting contact between said feeler and the piece, wherein said detecting device includes a microswitch (**23;23';23'';23'''**) with two stationary elements (**29,30;45,46;45',46';51**) made of electrically conducting material; the movable element (**27;27'**) of the detecting device also being made of electrically conducting material and being adapted for contacting said two stationary elements.

3. The head according to claim 2, wherein said microswitch (**23**) includes a thrust spring (**26**) acting on said movable element (**27**), the latter having a spherical shape, said second end of the wire (**38**) being adapted for contacting said movable element of the microswitch.

4. The head according to claim 2, wherein said

microswitch (**23**) includes a thrust spring (**26**) acting on said movable element (**27**), the latter having a spherical shape, the microswitch including a movable stem (**35**) and a device (**36;42;42';42"**) for guiding the stem in the direction of said longitudinal geometric axis, said stem having an end for contacting said movable element of the microswitch and the other end secured to said second end of the wire.

5. The head according to claim 4, wherein said wire (**38**) is made of steel and the second end of the wire is secured to the stem (**35**) of the microswitch by means of a coupling element (**37;37';37"**).

6. The head according to claim 5, wherein said device for guiding the stem includes at least one bushing (**36**), arranged near said stationary elements (**29,30**) and adapted to cooperate with the stem (**35**).

7. The head according to claim 5 or claim 6, wherein said device for guiding the stem includes a guide (**42;42';42"**) adapted to cooperate with said coupling element (**37;37';37"**).

8. The head according to claim 7, wherein said coupling element (**37'**) includes a substantially spherical surface adapted to cooperate with said guide (**42'**).

9. The head according to claim 7, wherein said device for guiding the stem includes a ball bearing (**43**) arranged between the coupling element (**37"**) and the guide (**42"**).

10. The head according to one of claims from 1 to 9, wherein said first end of the wire (**38;38';38''**) is secured to the movable arm-set (**5**) by means of a coupling device (**40**) for enabling adjustments in the direction of said longitudinal geometric axis.

11. The head according to claim 2, wherein said microswitch (**23';23'';23'''**) includes a device (**48;53**) for applying to the movable element (**27'**) a force in a direction substantially transversal with respect to said longitudinal axis for bringing the movable element into contact with the two stationary elements (**45,46;45',46';51**), said second end of the wire (**38'**) being secured to the movable element (**27'**) of the microswitch (**23';23'';23'''**).

12. The head according to claim 11, wherein said microswitch (**23';23'';23'''**) includes at least a stationary abutment surface (**49;44;44'**), the movable element (**27'**) being adapted for touching - upon contact of the feeler (**15**) with the piece - said abutment surface and disengaging from at least one of the two stationary elements (**45,46;45',46';51**).

13. The head according to claim 12, wherein said two stationary elements (**45,46**) have substantially rotational symmetry and are arranged adjacent in a transversal direction, and substantially parallel with respect to said longitudinal geometric axis.

14. The head according to claim 13, wherein the microswitch (**23'**) includes a stationary, shaped element (**49**) made from insulating material that defines said abutment surface.

15. The head according to claim 12, wherein said two stationary elements (**45',46'**) have substantially rotational symmetry and are arranged adjacent in a transversal direction, and substantially parallel with respect to each other in a direction that is inclined with respect to said longitudinal geometric axis.

16. The head according to claim 12, wherein said two stationary elements (**51**) have a substantially spherical shape and are arranged adjacent in a transversal direction.

17. The head according to claim 15 or claim 16, wherein the microswitch (**23'';23'''**) includes a flat element (**44;44'**) that defines said abutment surface, the abutment surface being substantially plane and arranged in the direction of said longitudinal geometric axis.

18. The head according to one of claims from 11 to 17, wherein said device for applying a force to the movable element of the microswitch includes an elastic element (**48**).

19. The head according to one of claims from 11 to 17, wherein said device (**53**) for applying a force to the movable element of the microswitch applies a magnetic attractive force.

20. The head according to claim 1, wherein said detecting device includes a position transducer (**56,57**) and the second end of the wire (**38''**) is secured to the movable element (**56**) of the detecting device.

21. The head according to claim 20, wherein said position transducer includes stationary windings (**57**) and the movable element of the transducer includes a magnetic core (**56**).

22. The head according to claim 21, wherein said position transducer includes a support (**55**) and a spool (**58**) that defines an axial hole for housing and guiding the support (**55**), the magnetic core (**56**) and the stationary windings (**57**) being coupled to said support (**55**) and spool (**58**), respectively.

23. The head according to any one of the previous claims, wherein said movable arm-set and said casing include a constraining system substantially of the cone-ball type (**4,6**) and two facing annular surfaces (**11,12**) for providing a substantially point-to-point contact.

24. The head according to claim 23, wherein there is foreseen - between said movable arm-set and said casing - a further constraining system (**21**) for preventing rotations of the movable arm-set about said longitudinal geometric axis.

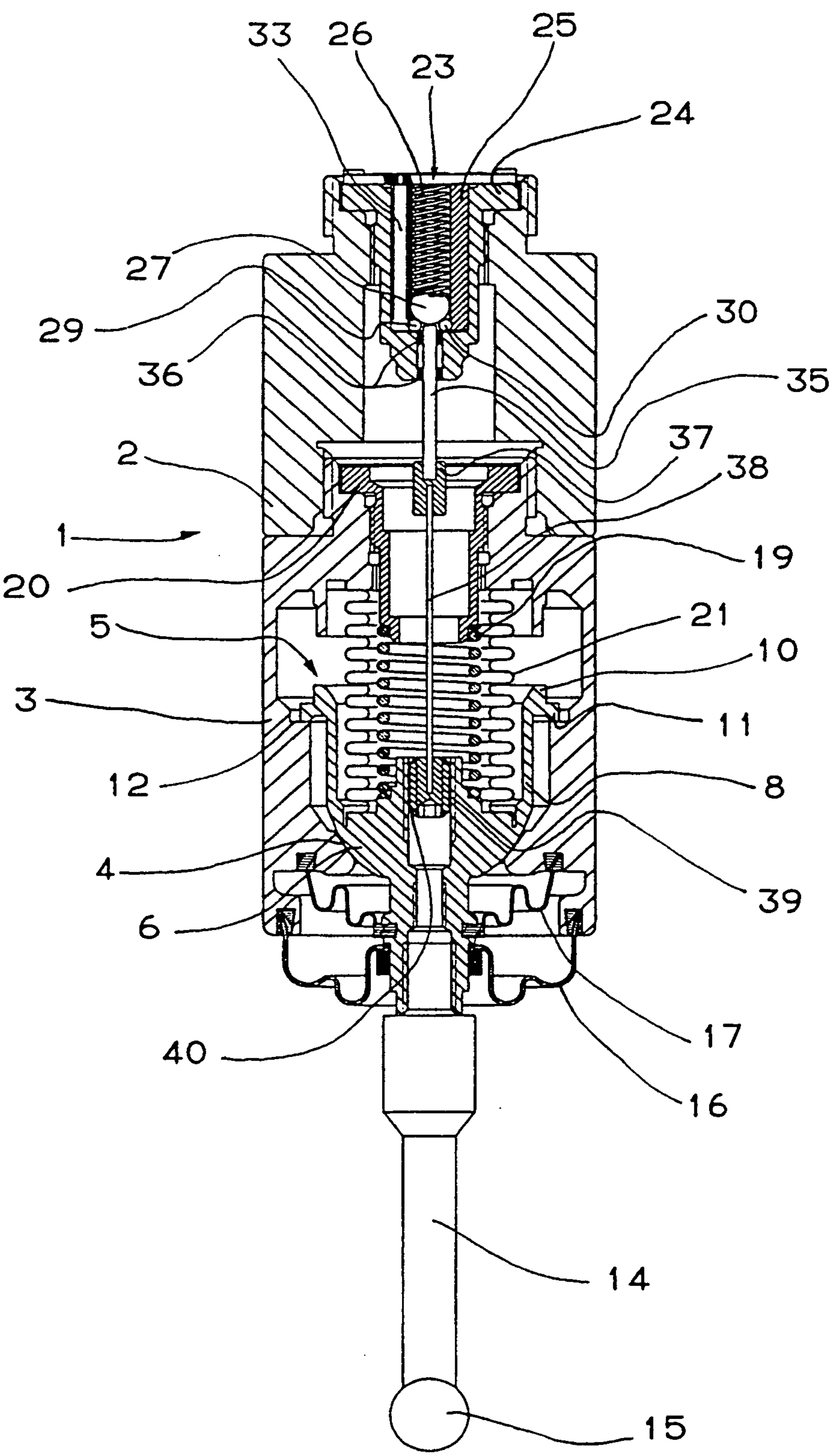
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Fig. 1

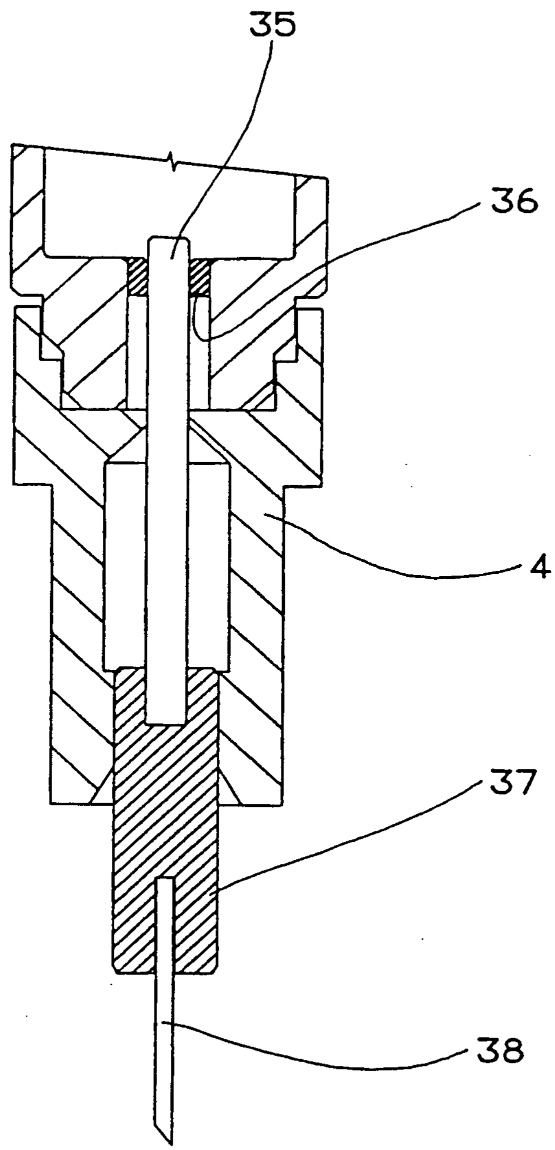

Fig.2a

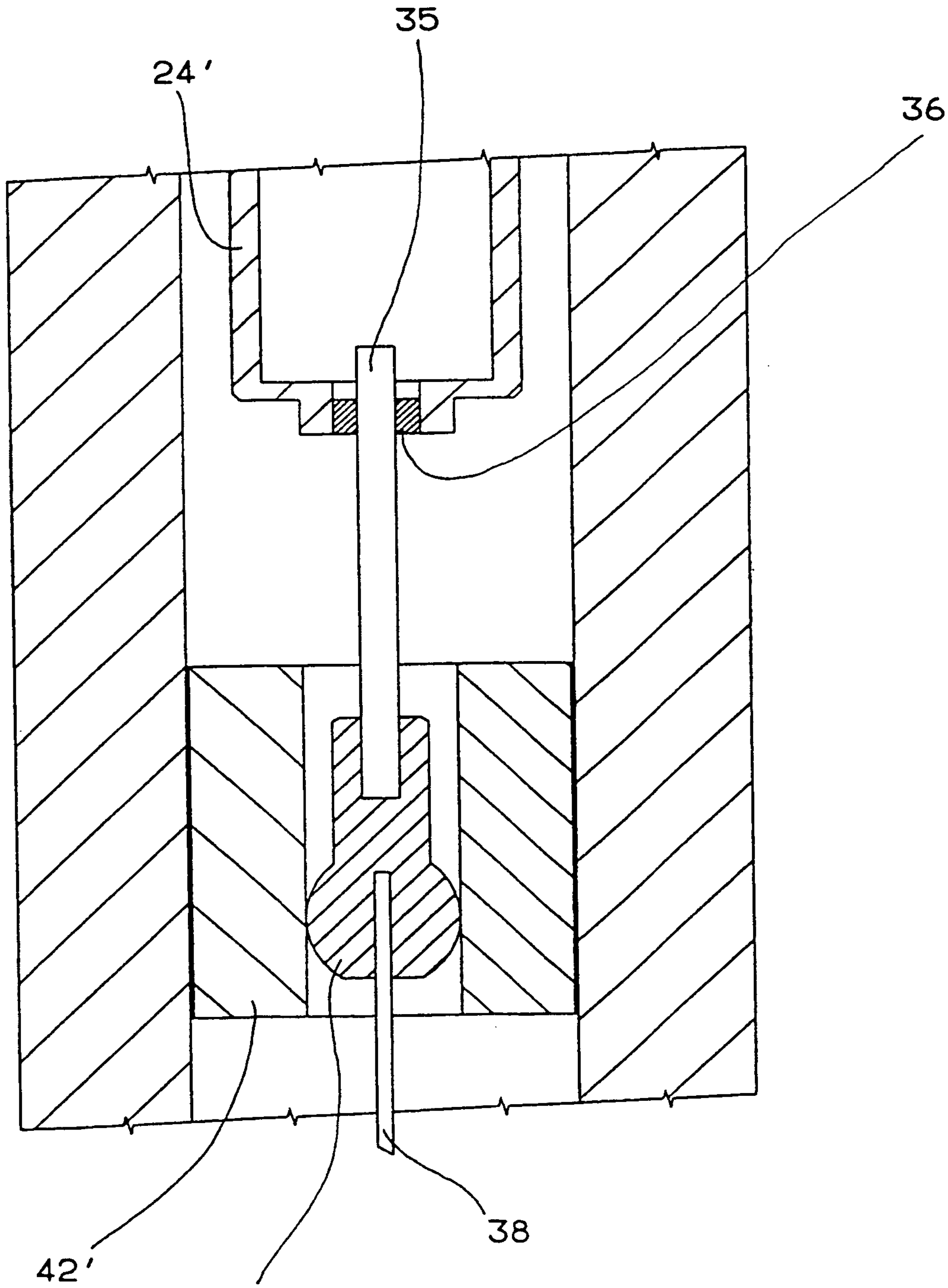

Fig.2b

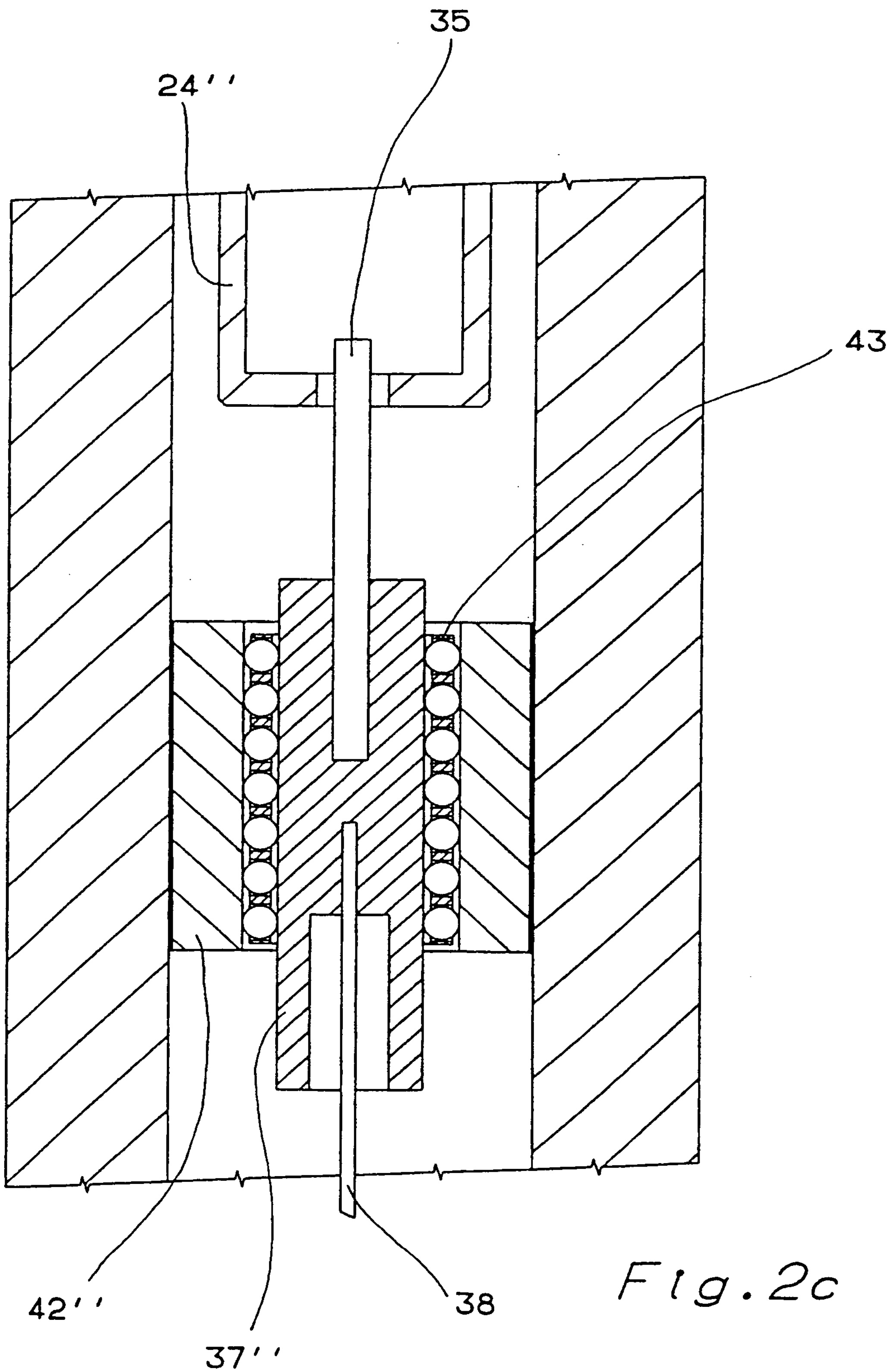

Fig.2c

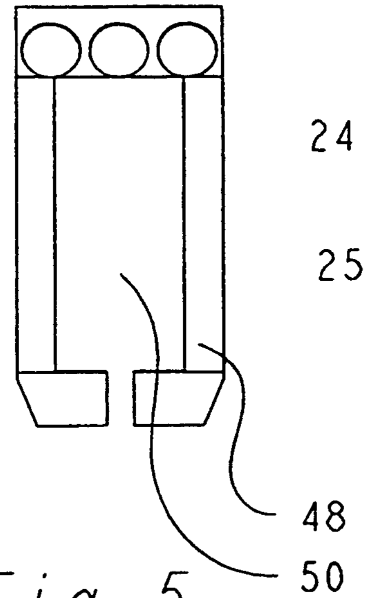

Fig. 5

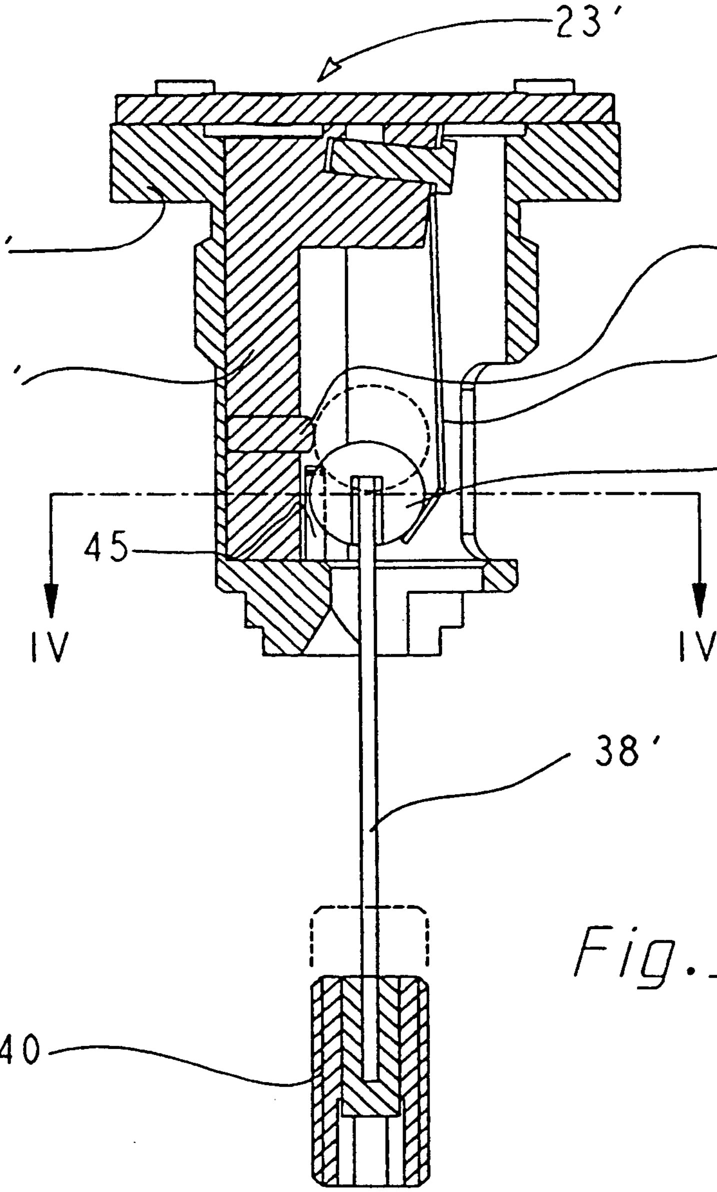

Fig. 3

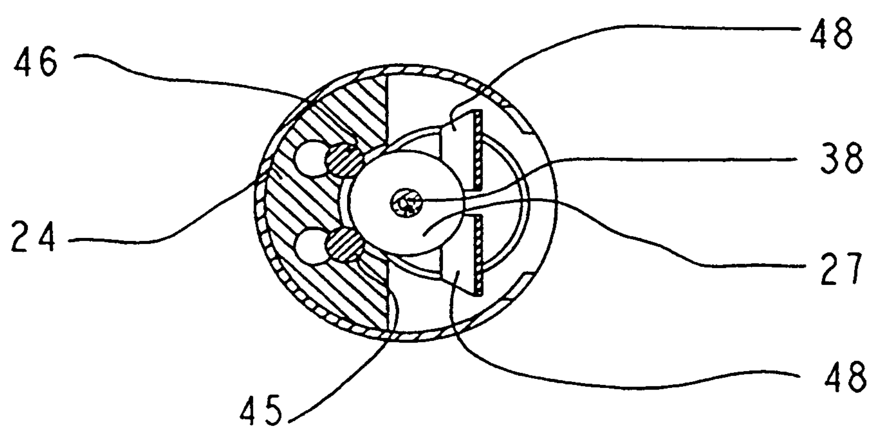

Fig. 4

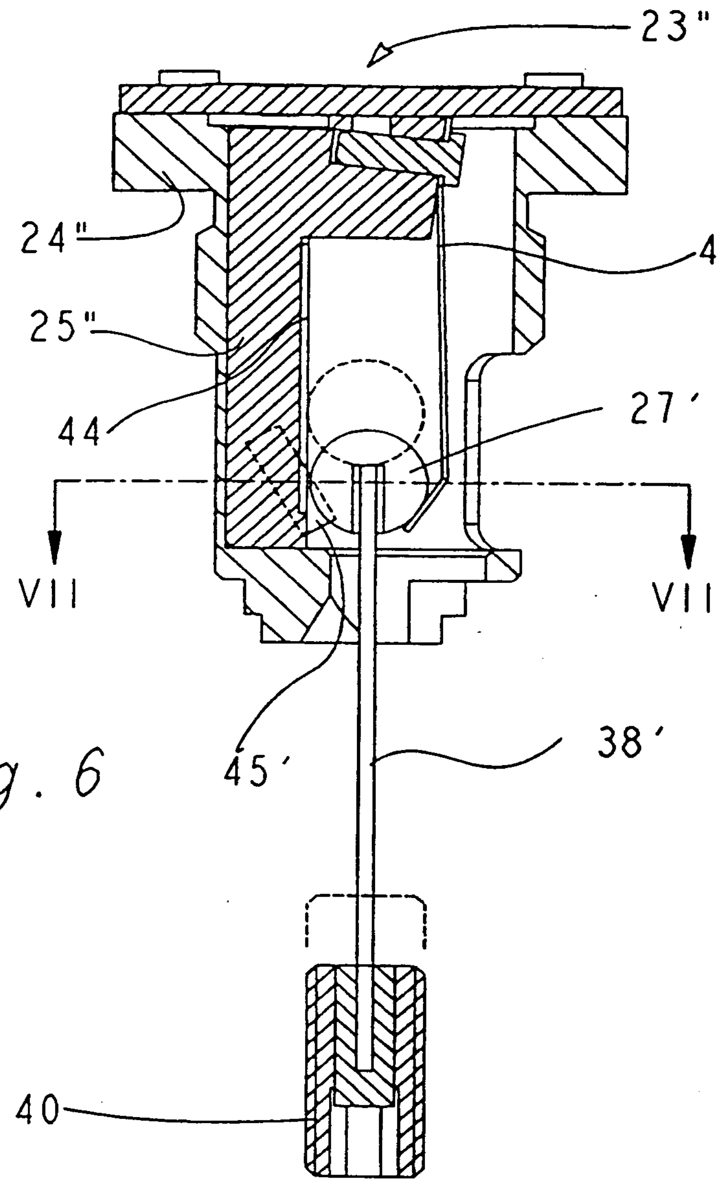

Fig. 6

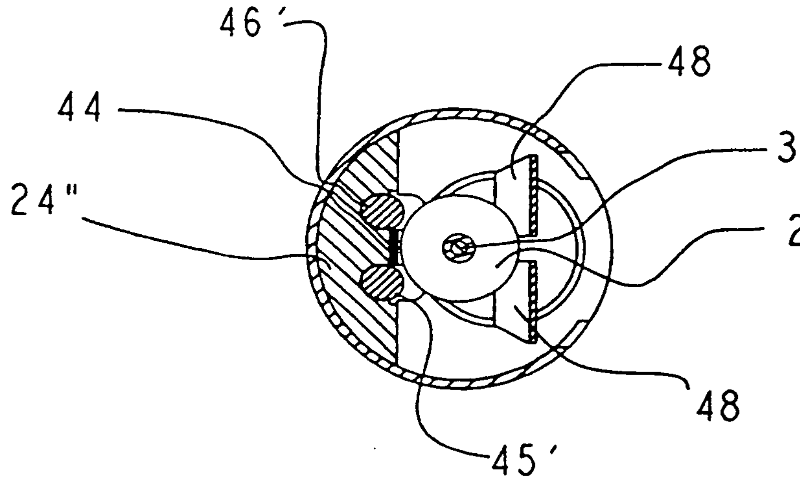

Fig. 7

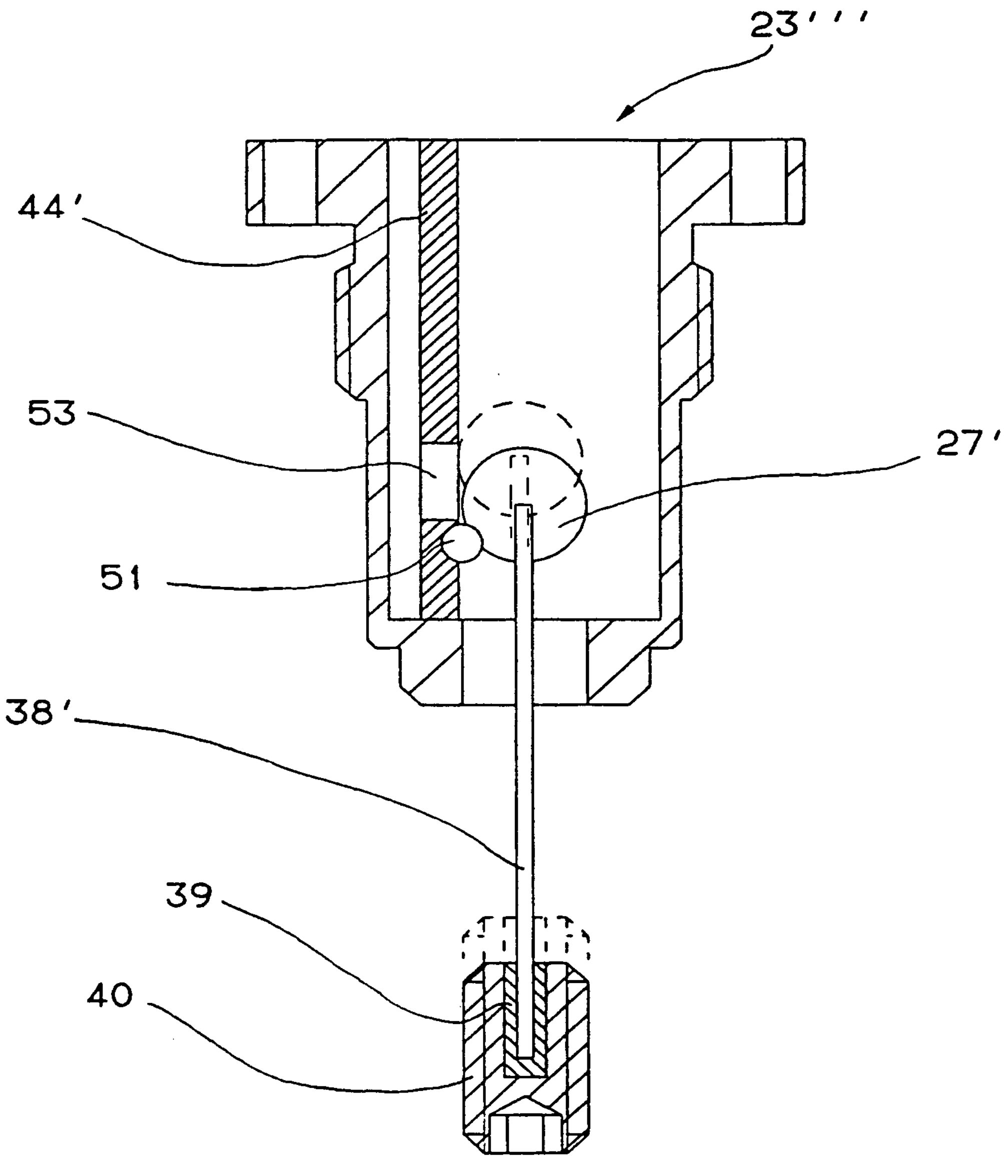

Fig. 8

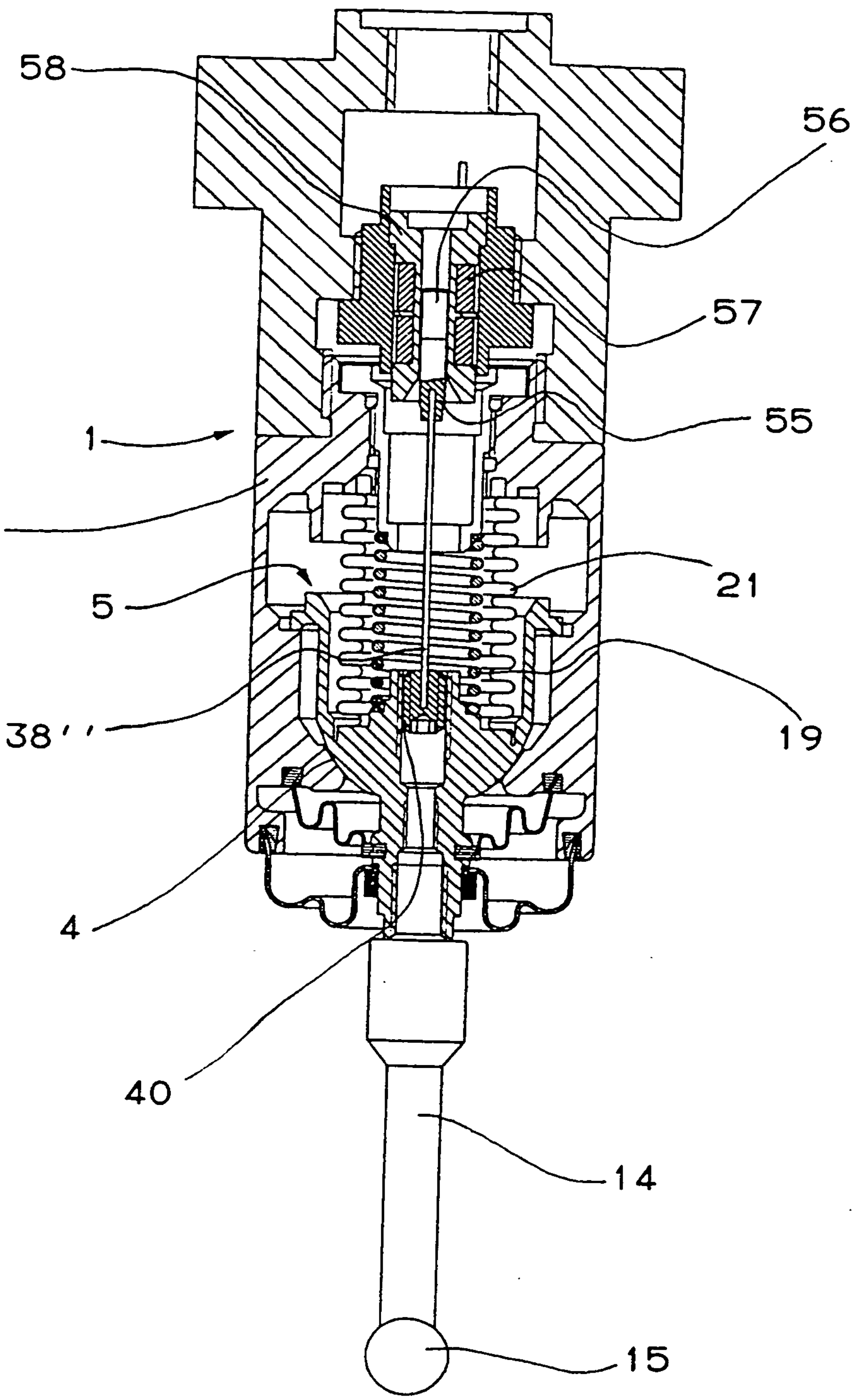

Fig. 9

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 99/06305

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01B5/012

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 187 614 A (ABIRU HISANORI ET AL) 12 February 1980 (1980-02-12) column 3, line 4 -column 4, line 23; figures 7-9	1,2
A	GB 2 208 934 A (MITUTOYO CORP) 19 April 1989 (1989-04-19) page 12, line 12 -page 15, line 6 page 21, line 10 - line 19; figures 1,2	1
A	US 4 530 160 A (FEICHTINGER KURT) 23 July 1985 (1985-07-23)	20
A	US 5 299 360 A (POSSATI DECEASED MARIO ET AL) 5 April 1994 (1994-04-05) cited in the application	1-24

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
20 December 1999	12/01/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Arca, G

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 99/06305

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